GENERATING VOLUMETRIC ROSE DIAGRAMS – PROGRAM generate_roses

Contents

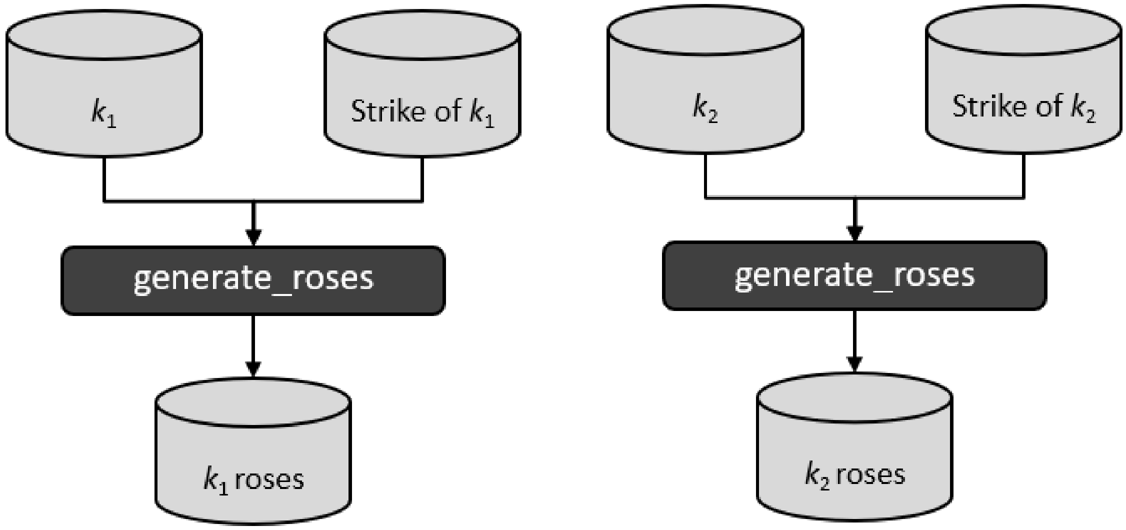
Objective

Rose diagrams are a common way for structural geologists to map the distribution of fault, fractures, and other lineaments on maps. However, hand picking the events to construct such a diagram can be quite tedious. Program **generate_roses** bins attribute vectors at each voxel that fall within a user defined window to generate a statistical approximation to a rose diagram. These diagrams can be converted to SEGY format and then imported into commercial workstation software for subsequent interpretation and integration with other types of data. The size and azimuthal resolution of the rose diagram are defined by the size of the analysis window, where the voxels in the output volume are used to generate a graphical image.

Computation flow chart

Program **generate_roses** reads in a principal curvature value (k1 or k2) and its corresponding strike, thereby defining a vector at each voxel. These voxels are then binned by azimuth within a user-defined window. The resulting bin count is then generated to form a rose diagram.

Display Tools: Program **generate_roses**



Output file naming convention

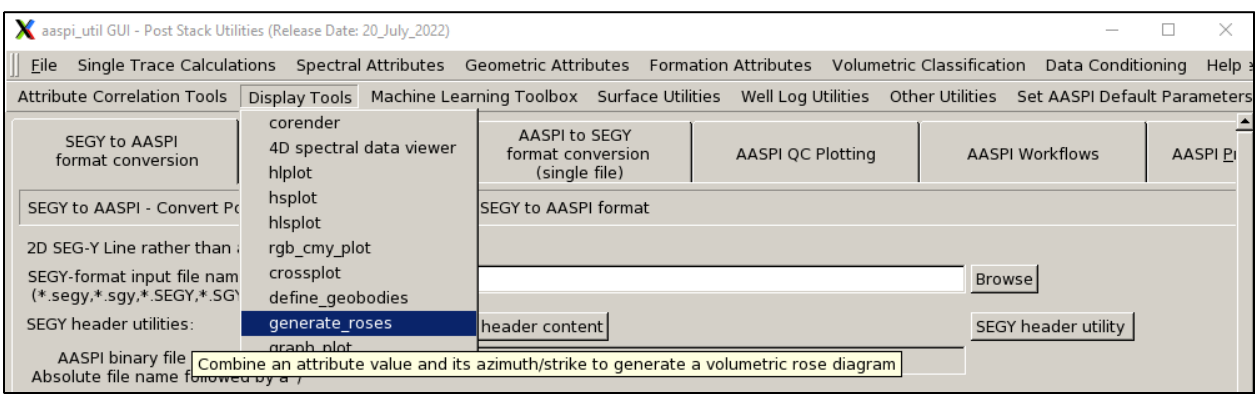
Program **hlsplot** will always generate the following output files:

Output file description	**File name syntax**
Rose diagrams	roses_*attribute*_*unique_project_name*.H
Program log information	generate_roses_*unique_project_name*.log
Program error/completion information	generate_roses_*unique_project_name*.err

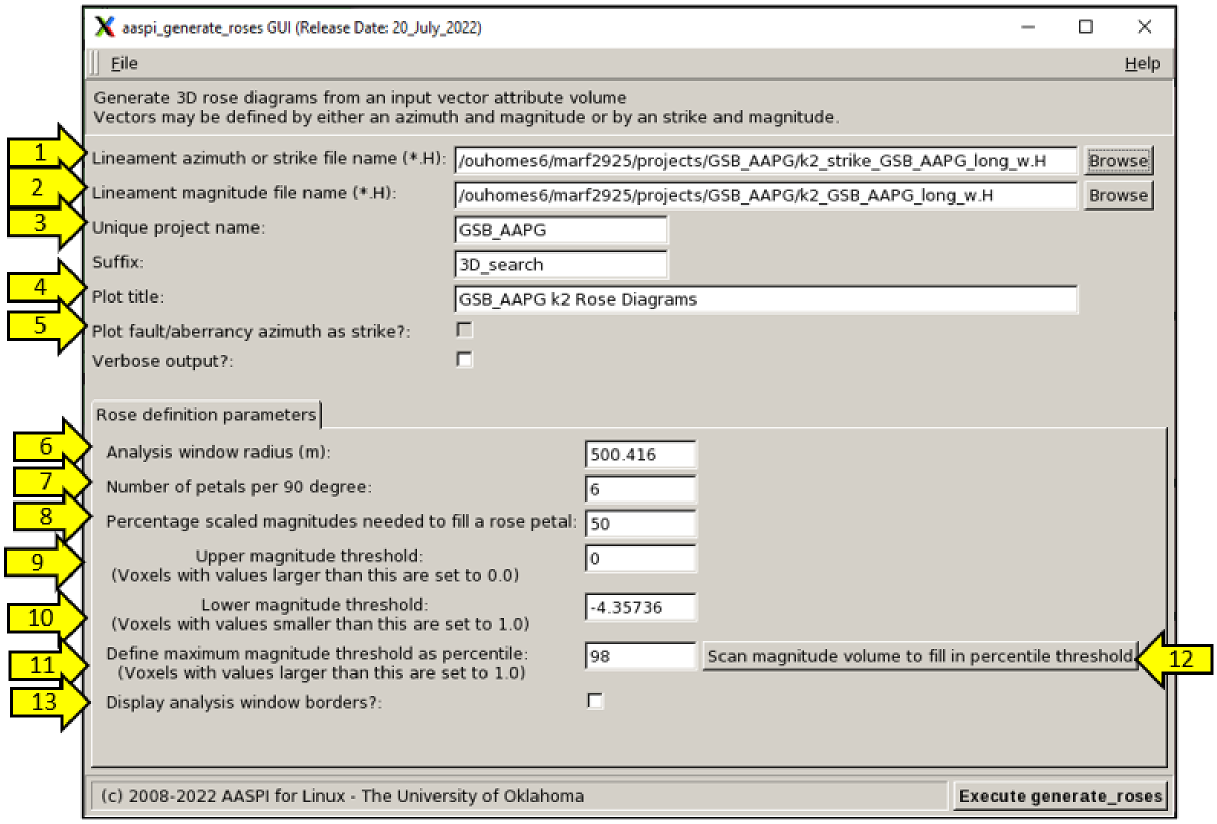
where the values in red are defined by the program GUI. The errors we anticipated will be written to the **.err* file and be displayed in a pop-up window upon program termination. These errors, much of the input information, a description of intermediate variables, and any software trace-back errors will be contained in the **.log* file.

Invoking the generate_roses GUI

To invoke program **generate_roses**, on the **aaspi_util** GUI select *Display Tools* and then select **generate_roses** on the drop-down menu:



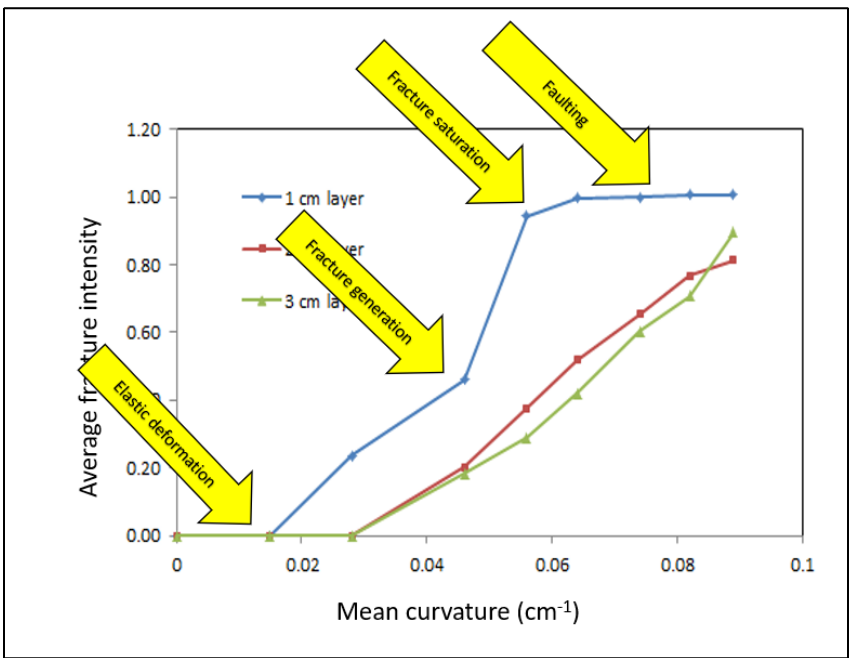
The following GUI will appear:



An attribute vector requires defining two volumes as input: (1) azimuth or strike volume, and (2) a magnitude or strength volume. Like almost all AASPI algorithms, please enter a (3) *Unique project name* and *Suffix*. Then (4) type or modify the *Plot title* of the rose diagram output to be plotted. This plot will also be stored in the output *.H file. The aberrancy and fault dip vectors are usually defined by a magnitude and an azimuth that ranges between -180° and +180°. If you check (5) Plot fault/aberrancy azimuth as a strike, the roses will be rotated to display strike and range between -90° and +90°. will be a maximum. In general, highly faulted zones will have both a major and a secondary fault system. For these types of surveys, a (7)

The Rose definition parameters tab

The first two parameters are simple – defining the (6) *Analysis window radius* (a square) and the (7) *Number of petals per 90 degree* sector. The (6) *Analysis window radius* defines the rectangle used to generate the statistics as well as the size (in survey bins) of the resulting rose stored in *.H (and if converted, *.SEGY) format. Proper scaling of the data to obtain useful roses may require two or three iterations. In this example the bin measure 25 m x 25 m, such that there are 41*41=1,681 bins analyzed that fall within the 1 km by 1 km analysis window. The histogram h_n for each petal n is computed using equations 1-3 in the *Theory* section below. If your hypothesis is that faults are correlated to natural fractures, you need to remember that there are two thresholds involved (White, 2013) who analyzed fracture correlation for several clay models as shown in these two figures and then correlated the results to outcrops:



Below the lower threshold of curvature (a measure of strain) the clay deforms elastically, and no fractures are generated. Above an upper threshold, the clay layer is saturated with fractures; further increases in curvature (strain) result in slip along several of the fractures, making them faults. The default values of the (9) *Lower magnitude threshold* and the (10) *Upper magnitude threshold* are defined by the limits of the input magnitude volume, in this case for most negative curvature, a value of -4.35736. To obtain a more robust value, I set (11) *Define magnitude threshold as percentile* (which is set to be *p*=98) and click (12) *Scan magnitude volume to fill in percentile threshold*. A pop-up window appears containing some statistics:

aaspi_completion_status

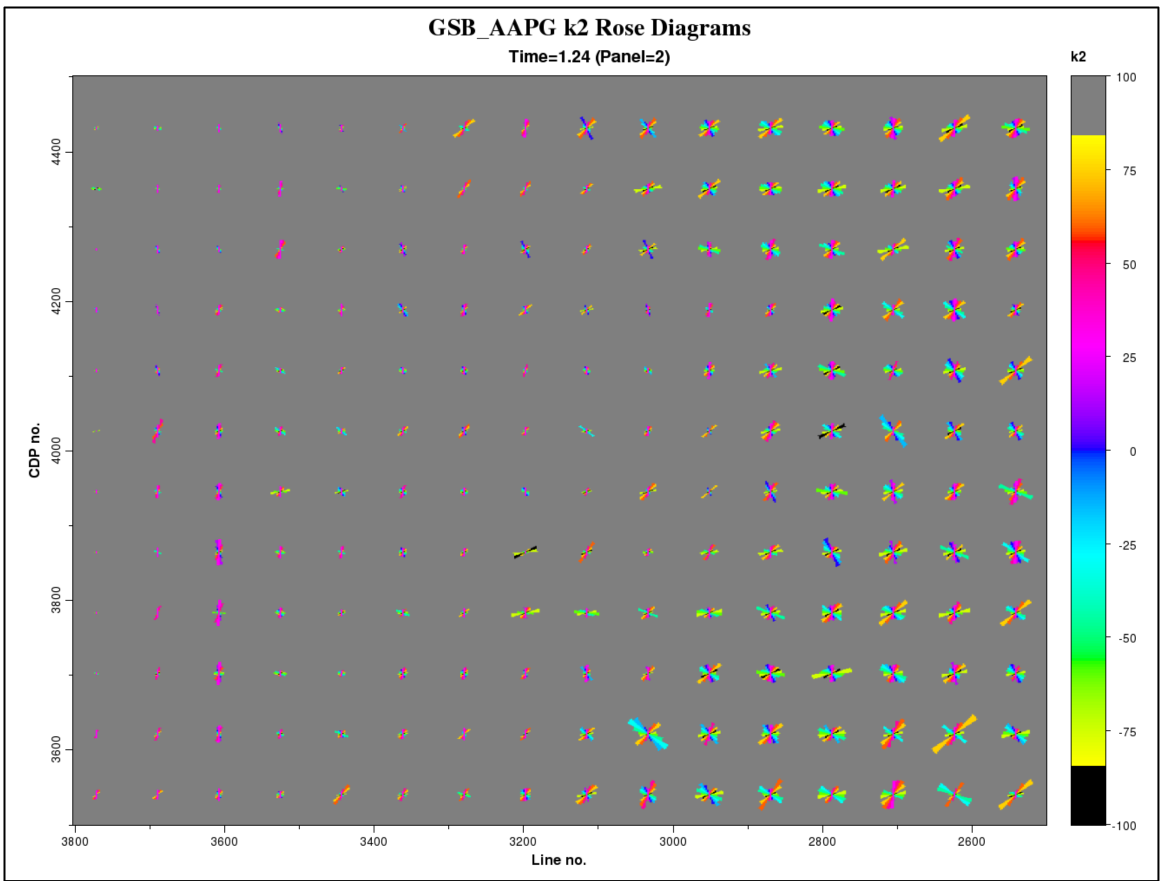
Program Completion Status

```
Number of samples analyzed =      962334
min_amplitude =  -1.753816
max_amplitude =  0.8648174
mean_amplitude =  -0.1221137
rms_amplitude =  0.1676222
  2.000000      percentile =  -0.5571577
  98.00000      percentile =  0.1631841
Normal completion. routine extract_data_statistics
```

The value of -0.557158 is copied in the *Lower magnitude threshold* text field:

Upper magnitude threshold: (Voxels with values larger than this are set to 0.0)	0
Lower magnitude threshold: (Voxels with values smaller than this are set to 1.0)	-0.557158

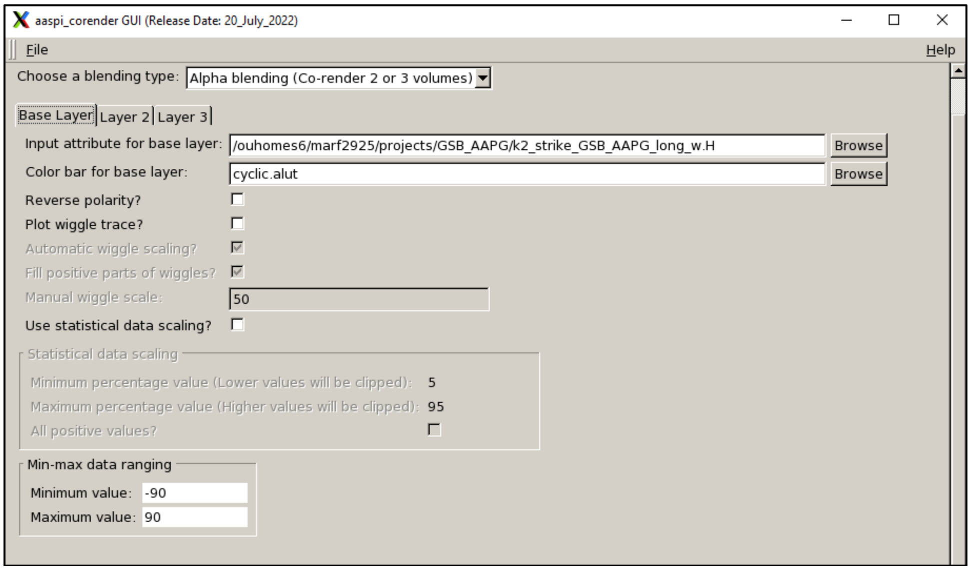
I test this value, run the program, and then using the **aaspi_util** *QC Plotting* tab to obtain the following time slice at *t*=1.24 s:



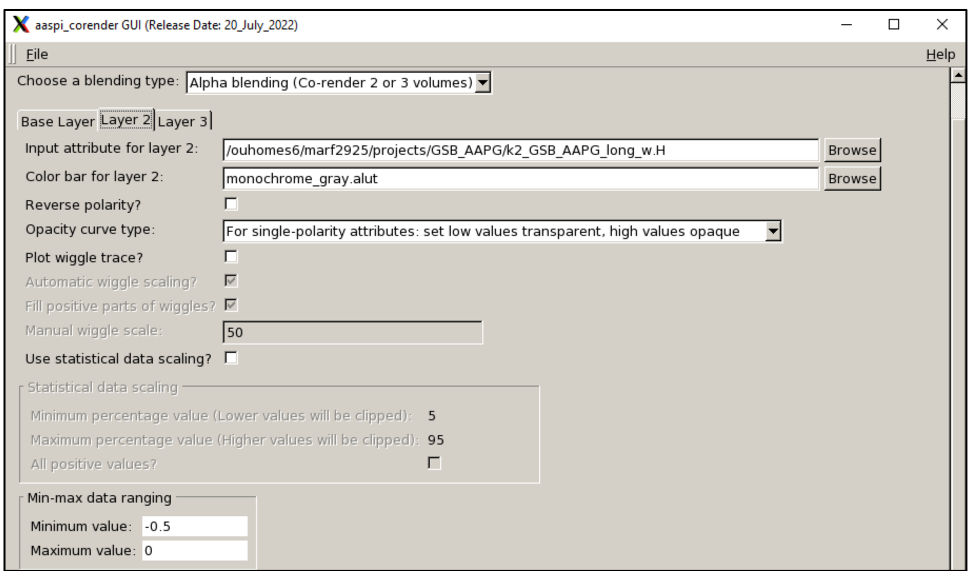
Example 1: Mapping most-negative curvature lineations in the Great South Basin

Display Tools: Program **generate_roses**

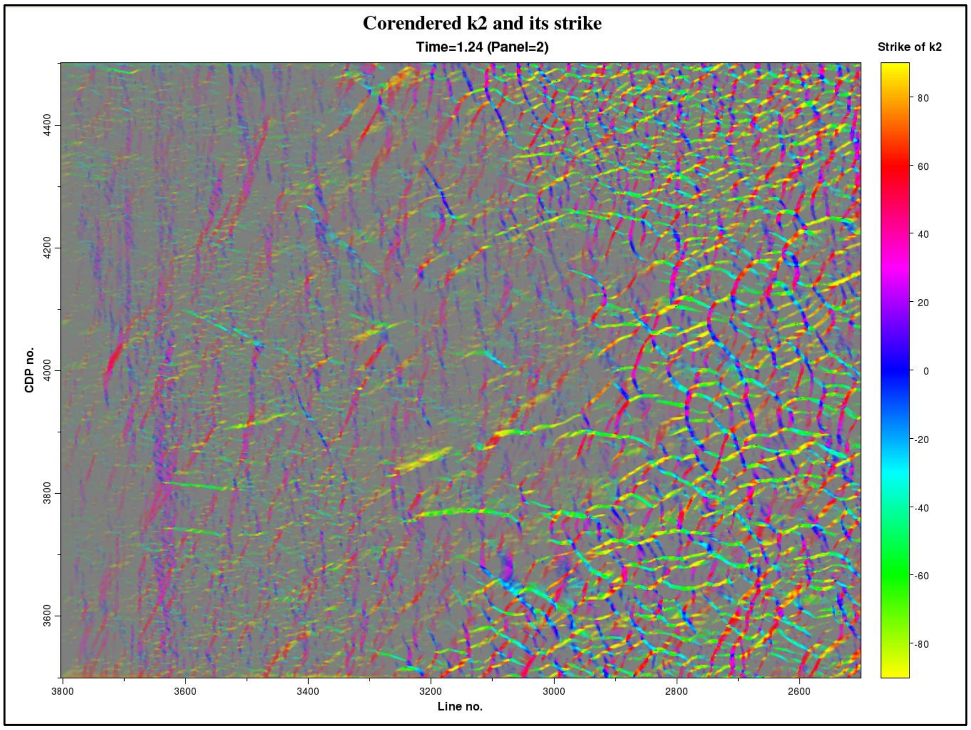
To better understand the previous image, we first need to examine the lineations as they are normally displayed. Here, I use program corender to display the strike of the most-negative curvature and its value using the following parameters for the *Base Layer*:



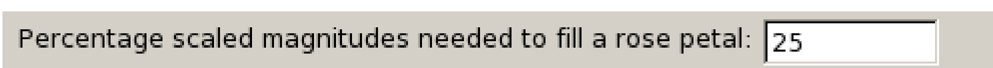
and these parameters for *Layer 2*:



Note that because I wish to so negative-valued lineaments that I have chosen a *Minimum value*=-0.5 (approximately at the 98 percentile) and a *Maximum value*=0.0. Because I want the negative values to be transparent (to see the underlying strike) and the values near zero to be opaque (gray) I set my *Opacity curve type* to be *For single-polarity attributes: set low values transparent, high values opaque*. I obtain the following time slice at *t*=1.24 s:



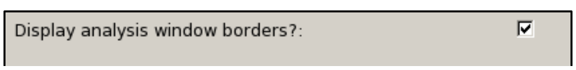
These images correlate nicely, where the corendered image above was also graphically clipped at the 98 percentile (k_2=-0.577). If I wish to make the roses larger, I need to decrease the value of the (8) *Percentage of the scaled magnitude needed to fill a rose petal* to be 25% rather than 50%:

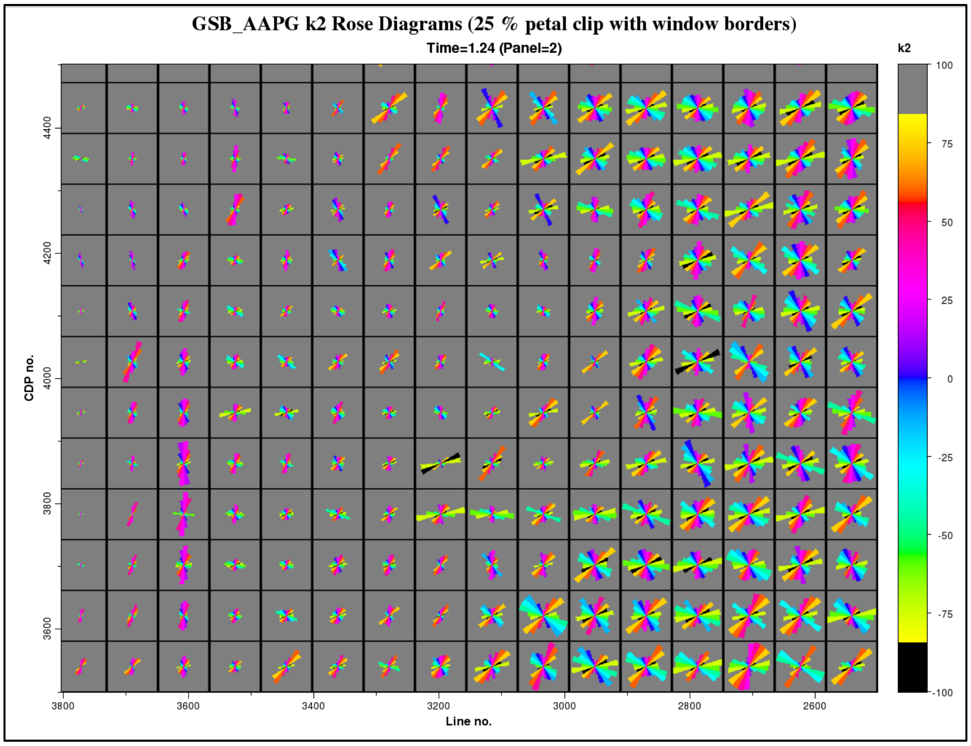


Then rerun the program and generate the following plot:

where I note that some of petals in the lower right corner are now clipped.

The last option (13) Display analysis window borders graphically outlines the range of the analysis window (and the maximum size of the roses).





Loading the data into commercial workstation software

You will note that the color bar on the right of the previous figures range from -100 to +100, even though the strike ranges between -90° and +90°. The voxels showing the background of the roses are set to have a value of +100, while voxels corresponding to dead traces and the limits of the analysis window are set to be +100. You will therefore need to make sure the imported *.SEGY volume is scaled to range between -100 and +100, to construct a cyclic color bar between -90° and +90° with end members between -91 and -100 and +91 and +100 to be an appropriate background color. These background colors can be set to be transparent in 3D visualization software, allowing the interpreter to see how the rose diagrams change with depth through rocks of different strength and of different age (Chopra et al., 2009; Mai et al., 2009).

Theory

At each location (*j,k*) within a rectangular analysis window $|j\Delta x| \le J\Delta x \le r_{max}$, $|k\Delta y| \le K\Delta y \le r_{max}$, at fixed time slice, we have a vector defined by a magnitude m_{jk} and an azimuth and a strike φ_{jk}. Within this window, we wish to define a histogram h_n of magnitudes for each binned azimuth $n\Delta\varphi$, such that

$$h_n = \sum_{j=-J}^{+J} \sum_{k=-K}^{+K} w\left(m_{jk}\right)\Pi\left(\frac{\varphi_{jk} - n\Delta\varphi}{\Delta\varphi}\right), \qquad (1)$$

where the gate function Π(x) is defined as

$$\Pi(x) = \begin{cases} 0 \text{ if } |x| > \frac{1}{2} \\ \frac{1}{2} \text{ if } |x| = \frac{1}{2}, \\ 1 \text{ if } |x| = \frac{1}{2} \end{cases} \qquad (2)$$

and the weighting function $w(m_{jk})$ is defined for positive magnitudes as

$$w(\mathrm{m_{jk}}) = \begin{cases} 0 & \text{if } \mathrm{m_{jk}} < m_{\min} \\ \frac{m_{jk} - m_{\min}}{m_{\max} - m_{\min}} & \text{if } m_{\min} \le m_{jk} \le m_{\max} \; . \\ 1 & \text{if } m_{jk} > x_{\max} \end{cases} \qquad (3)$$

For negative values encountered with most-negative curvature, the magnitude scaling is reversed.

Clipping rose petals

If all values in an analysis window exceed the threshold and are assigned a value of 1.0 using equations 1-3 and are distributed equally over all *N* petals, each petal will have a count of

$$h^{\max} = \frac{(2J+1)(2K+1)}{N}. \qquad (4)$$

If any value $h_n > 0.01ph^{max}$, where *p* is the *Percentage to fill a rose petal* defined by the GUI, it will be clipped to be the maximum radius of the rose.

References

Chopra, S., K. J. Marfurt, and H. T. Mai, 2009, Using 3D rose diagrams for correlation of seismic fracture lineaments with similar lineaments from attributes and well log data: 79th Annual International Meeting of the SEG, Expanded Abstracts, 3574-3577.

Mai, H. T., K. J. Marfurt, and M. T Tan, 2009, Multiattribute display and rose diagrams for interpretation of seismic fracture lineaments, an example from the Cuu Long Basin, Vietnam: The 9th SEGJ International Symposium on Imaging and Interpretation - Science and Technology for Sustainable Development, paper 1D93.

White, H. G., 2013, Fracturing of Mississippi Lime, Oklahoma: Experimental, seismic attributes, and image log analysis: M.S. Thesis, The University of Oklahoma, 58p.